ON INDIAN PARASITIC FLIES.

BY

HAROLD RUSSELL, F.L.S., F.Z.S.

II

With Two Plates

(*Continued from page* 380 *of this Volume.*)

III.

THE MUSCOIDEA.

The next five families that must be mentioned in connection with parasitism and Diptera (*Tachinidæ*, *Dexiidæ*, *Muscidæ*, *Sarcophagidæ* and *Œstridæ*) all belong to the super-family Muscoidea of Townsend. It is very noteworthy that this Muscoidean stock has developed three separate and absolutely distinct types of parasitism, or at least feeding, on mammals. * All three have the same aim, which is to nourish the dipterous larvae at the expense of the Mammalia. What is interesting is that each of the three has attained the same result in such fundamentally opposite ways.

1. In the first group come *Cuterebra* (*Œstridæ*) and its allies. The end is attained by subcutaneous or internal larval endoparasitism. The larva does all the feeding and the imago takes no nourishment whatever. To such a complete extent does this prevail that the adult mouthparts are atrophied and do not function at all. The Oestrid habit of parasitism seems to be the oldest of the three.

2. In the second division we have *Glossina* (*Muscidæ*) the genus which includes the tse-tse flies. The same result is attained by supracutaneous imaginal blood-sucking which strictly speaking is not ectoparasitism. This is the exact antithesis of the preceding. The adult fly does all the feeding by blood-sucking. But it retains and nourishes the larva within the oviduct until full grown. The larva is then extruded and almost immediately becomes a pupa without feeding any more.

3. In the third division we have the case of the Congo floor-maggot (*Auchmeromÿia*), another of the *Muscidae*. The fly produces a blood-sucking larva. The desired result is here obtained by supracutaneous larval ectoparasitism. It is a remarkable method because unique among dipterous larvae. The larva sucks blood ex-

* C. H. T. Townsend. "The Taxonomy of the Muscoidean flies 1908) Smithsonian Miscellaneous Collections. Vol. 51.

ternally by mechanical means. It pierces the skin of sleeping persons with its small sharp jaws and imbibes their blood. The habit is without parallel among Diptera. The larva is a footless maggot with very minute jaws and cannot attach itself to the skin of the host except by the mouth-parts. It cannot cling whilst piercing by any structure except the mouth-hooklets. Such a habit could hardly have arisen but for the fact that the African natives sleep on mats on the earthen floors of their huts. The larvae, which probably originally fed on foul liquids, are common beneath children's mats which become stained with urine. The adult flies are attracted by the smell and lay their eggs under the mats.

It has been stated previously that the parasitic habit of the *Œstridae* is apparently the most ancient. The *Glossina* habit comes next. The habit of blood-sucking of the Congo floor-maggot is evidently a comparatively recent development. The stages of parasitism can thus be placed in order. In the *Hippoboscidae*, which are imaginal parasites and which will be described in the section on Pupipara, the peculiar mode of reproduction of *Glossina* is carried a stage further. In *Glossina* the larva when extruded has sufficient power of movement to find a suitable place for pupating; thereupon its integument becomes chitinized to form the pupal envelope. The Hippoboscid larva upon extrusion at once undergoes this change; the Hipposboscid female therefore deposits the larva in a situation suitable for it to remain during the pupal period.

The *Hippoboscidæ* are probably an offshoot from the old muscid stock. The *Œstridæ* are possibly an earlier off-shoot in an opposite direction from several stems of the same stock. Townsend regards the *Œstridæ* as a polyphyletic group showing affinities with various sub-families and tribes of Muscoidea. Its preponderating characters are due to similar parasitic modes of life in the larvae with corresponding similarity in the adults. These suggestions are enlightening when one tries to discover the origin of the different forms of parasitism among flies.

J. Pantel in his "Recherches sur les Diptères à larves entomobies" has suggested ten groups of Muscoid flies founded on reproductive and parasitic habits.* These may be compared with the five Tachinid groups of Townsend referred to further on and based also on reproductive habits. Townsend considers that Pantel's

* Two parts of this great and interesting contribution have appeared: I .Caratéres parasitiques aux points de vue biologique, ethologique et histologique. La Cellule (1910) Vol 26 pp. 27-216. II. Les enveloppes de l'oeuf avec les formations qui en dépendent; les dégats indirects du parasitisme (1913) Vol 29 pp. 1-289. Each part contains a bibliography of the literature on parasitism in the Diptera. The earlier part of Pantel's two papers has been reviewed and criticised in English by C. H. T. Townsend: "Review of work by Pantel and Poltchimski on reproductive and early stage characters of Muscoid flies." (1911) Proc. Ent. Soc. Washington., Vol 13, p. 151.

grouping becomes in a large measure a true and natural one though not founded on the ordinary taxonomic characters.

The ten groups are as set out below :

1. Species which glue a short flattened macrotype egg to the host's body.
2. Species which deposit on the food of the host a microtype egg containing the developed maggot and destined to be swallowed.
3. Species extruding large and strong larvae known as ordinary flesh maggots.
4. Species which deposit maggots (naked or in choria) in the path of the host.
5. Species which deposit maggots (naked or in choria) probably in the neighbourhood of the host.
6. Species which deposit maggots (naked or in choria) on the body of the host.
7. Species which introduce into the host's body maggots (naked or in choria) by means of separate instruments of perforation and injection.
8. The same but by means of a combined instrument to perforate and inject.
9. Species destitute of incubating apparatus but provided with a variable chitinous ovipositor for introducing the undeveloped eggs into the host.
10. Species which deposit on the host a pediceled egg in which the maggot is already well developed.

Examples of most of these groups will be met with in the five families now to be dealt with.

Tachinidæ and Dexiidæ. The habits and life histories of these two families are so much alike that they can be treated together. The *Dexiidæ* closely resemble the *Tachinidæ*. Willistone considers that the distinction between the two families is very difficult to make, if it be not actually evanescent. Townsend lumps most of the old *Dexiidæ* with the *Tachinidæ*. Both are smallish to fair-sized hairy flies with strong legs and conspicuously large squamae. The habits of the mature Tachinid flies are much the same in all the members of the group which is a large one. They are found on plants and on leaves or flowers which are the haunts of the hosts which they seek to parasitize. So far as is known all the larvae are parasitic in habit and the parasitism is confined to the larval stages of other insects. The individual female Tachinid is not always particular in the choice of the species of larvae which she parasitizes.

In the Muscoidean flies the integument is furnished with many large bristles called *machrochaetæ*. In the *Tachinidæ* this hairiness is most characteristic and is of some interest in connection with their parasitic habits which involve running about and searching for caterpillars. Osten-Sacken has pointed out that these bristles occur

almost solely in flies with pedestrian habits and he concludes that the *machrochaetæ* are organs of orientation which fulfil much the same function as a cat's vibrissae or whiskers. If it be the truth that the bristles on the Tachinid and other flies are connected with pedestrian habits, it is worth noticing in confirmation that in another utterly different animal, namely the three-toed Sloth, whose habits are the reverse of pedestrian, facial vibrissae are absent.

There can be little doubt that parasitism in the *Tachinidæ* is fairly recent and not nearly so effective and well evolved as, for instance, in the parasitic Hymenoptera with almost similar habits. Unlike most of the parasitic Hymenoptera, these Dipterous parasites do not usually confine themselves to one particular host. By far the largest number of species are parasitic on lepidopterous larvae. The lives of some 400 species have been more or less studied. About 70 are parasitic on Hymenoptera. Then follow as hosts: Coleoptera; Orthoptera; Hemiptera; and other Diptera in diminishing numbers.

The precise adjustment of perfect parasitism has not yet been attained by these flies and they make two frequent blunders with disastrous results to their offspring. The first consists in laying eggs on a caterpillar which is about to moult; the second, in laying eggs on a caterpillar which has been already parasitized, with the result that some or all of the young Tachinids perish of starvation. This points to the comparatively recent adoption of this mode of life. Yet when all is said the Tachinid flies are a successful family. To secure successful parasitism five forms of reproductive habit have been evolved in the *Tachinidæ*. They are thus summarized by Townsend:—

1. Host-oviposition.
2. Leaf-oviposition.
3. Supracutaneous host-larviposition.
4. Subcutaneous host-larviposition.
5. Leaf-larviposition.

These five forms of reproduction are arranged above in order of probable antiquity. The placing of the egg upon the host is thought to be the most primitive, and the placing of the larva on a leaf, where the host will pass, appears to be the most recent stage. From the commonsense view of the habits of these flies this seems natural; and it is also confirmed by a study of the external characters of the flies.* A few words may be added on each of these five methods of reproduction.

1. *Host-oviposition.* The eggs are laid by the female Tachinid on the caterpillars. The eggs are usually thin shelled and in some

* C. H. T. Townsend (1908) "A record of results from rearings and dissections of Tachinidæ." U. S. Dept. Agriculture, Bureau of Entomology. Tech. Series No. 12 Pt. VI. pp. 95-118.

species on pedicels. The maggots hatch out and penetrate the caterpillars. In some cases the segments of the parasitic maggot's body are furnished with rows of minute spines directed backwards. These help progression over the caterpillars skin and are aids to penetration also. In the second stage of the maggot's life, having served their purpose, the spines for the most part disappear. A very marvellous adaptation appears in the third or penultimate stage. The penultimate stage of many Tachinid maggots presents this strange peculiarity. During the two first stages the maggot derives no air from the outside. In the third stage it protrudes a pointed posterior end through the skin of the caterpillar. The protruded end becomes highly chitinised from exposure to the air and ends in a pointed tube in the base of which lie the posterior stigmata. Through this protruded tube the maggot obtains air. The fourth and last stage of these maggots is passed living free inside the hosts. The cast skins of the penultimate stage remain fixed in their place protruding through the caterpillar's skin. A few species remain as last-stage maggots within the chitinised cast skin and transform to pupæ inside the caterpillar skin. Most Tachinids pupate outside the host and the exit is fatal to the host.

2. *Leaf-oviposition.* The suggestion that the parasitic maggot could obtain entrance into the host by the egg in which it is enclosed being swallowed by the caterpillar, was received with incredulity when originally put forward. The facts are now well established. The eggs are swallowed by the caterpillars and hatch within their alimentary canal. In such cases the eggs are minute, perhaps not a fiftieth part of the usual size, though the flies laying them may be larger than the average size. The piece of leaf swallowed by the caterpillars may be six or eight times the size of one of those eggs. Where a fly produces minute eggs it is certain that when matured they will be black and highly chitinised. They are intended to stand exposure and swallowing. Probably such eggs when deposited on leaves can retain their vitality for a long while. Probably also they are not laid until the embryo is well developed; the digestive juices and the conditions in the alimentary canal act on the chitin, weaken the shell and release the maggot. It is certain that somehow the egg must hatch within a few hours of being swallowed else it would pass through the gut of the caterpillar and perish. A very small egg cannot have a thick chorion and is therefore provided with a chitinised thin one which withstands atmospheric conditions better than an unchitinised thick one. Some eggs are protected by a reticulated surface which possibly preserves them from injury in the swallowing. Thus the history of the species can be read from the uterine eggs dissected from the female Tachinid.

3. *Supracutaneous host-larviposition.* This brings us to another

phase of Tachinid parasitism but the leap from reproduction by living larvæ is not so abrupt as it may seem. There are species of *Tachinidæ* in process of transition. Female Tachinids of certain species may deposit eggs almost undeveloped, or at any stage of the development of the embryo, or may even perhaps deposit living maggots. When the larva is deposited on the skin of the caterpillar it is exposed to much the same danger as an egg; it may be accidentally or purposely removed by the caterpillar and if the host moults before the maggot has managed to penetrate this is fatal.

4. *Subcutaneous host-larviposition.* Another step forward is attained if the parasitic maggot can be immediately introduced beneath the host's skin. The females of those Tachinids which have attained this higher grade of efficiency are furnished with a long curved sheath which tapers down to a point and is microscopically fine and sharp. The ovipositor fits into the base of this organ and with this organ the female Tachinid punctures the caterpillar's skin at the moment when the living maggot is being extruded. Until Townsend and his assistants worked at this group (1908) the habit of introducing the living maggot within the skin of the host was never suspected in the *Tachinidæ*.

5. *Leaf-larviposition.* It is unexpected to discover that Tachinid parasitism reaches, apparently, the highest efficiency in those forms which deposit their maggots on leaves to wait the passing by of a chance host. The maggots, in a fashion wonderful to relate, are securely attached to the surface of the leaf at the moment of birth by a membranous cup-shaped case which holds the posterior end of their bodies. The maggot can reach out in all directions and moves constantly on feeling the proximity of a host. When undisturbed it lies at length on the leaf but on being touched it becomes excitedly active seeking to attach itself to the expected host. No sooner does it lay hold of a caterpillar than it is torn from the cup-shaped attachment by the motion of the caterpillar and its own exertions.

It would be thought perhaps that the chances of parasite and host meeting under such conditions were very remote. But this is not the case, for the Tachinid female selects leaves and stems where caterpillars have already crawled and usually deposits a maggot where a silken thread has been left by a caterpillar. Possibly the sense of smell guides the flies in selecting these silken threads. In such a case, where the caterpillar follows the thread back, it is sure to pick up the maggot on the way.

A second advantage is gained by this habit in the greater certainty with which a maggot can become attached to a caterpillar especially if one of a hairy sort. Being placed where the caterpillar will pass *over* it, the maggot can attach itself with greater ease to the under parts where hairs are sparse and short. If the female Tachinid tried to

deposit it on the back of the caterpillar it would be much less certain of securing an attachment. The alarming size of the fly, the consequent frantic efforts of the caterpillar to shake off the maggot and the hairs which protect the back and sides of the caterpillar with an almost impenetrable thicket, are thus circumvented.

The maggots of this group are protected by a thicker and darker integument than the usual white and thin-skinned forms, since they have to pass a time exposed to the atmosphere.

Tachinids form an enormous group of parasitic flies with wide geographical distribution. Over 300 genera have been established. Classification and nomenclature are in a state of flux. The Indian species have hardly been studied at all and must be very numerous.* Here is a rich and almost virgin field for Indian collectors and observers.

Muscidæ and Sarcophagidæ. Although most of the species in these two allied families are not parasitic at any stage of their existence, others are always or occasionally parasitic as larvæ, and a few are blood-suckers in the adult stage. The frontier which divides these two families is undetermined. The Muscoidea are of extremely recent evolution: in fact their evolution is still going on. In these two families we can see parasites in the making. It has already been pointed out that a promiscuous choice of hosts is evidence, and indeed a necessary result, of the recent origin of the parasitism. No fixed habits comparable with those of the Hymenopterous parasites are to be found in any parasitic Muscoidea except the *Œstridæ*.

Muscidæ. To this family belong the only blood-sucking Cyclorrhapha, other than Diptera pupipara if these latter are to be regarded as one of the cyclorrhaphous sections. The blood-sucking Muscids, which as everyone knows, are well represented in India, belong to the three sub-families following:

(1) *Philæmatomyinæ:* with a single genus and three species all Indian.

(2) *Stomoxydinæ:* with some six genera and many Indian species.

(3) *Glossininæ*: with a single large genus: the African Tse-tse flies.

These three blood-sucking groups contain perhaps some potential or embryo parasites. The pupiparous habit is highly developed in the last of the three; and it is but a step to the *Hippoboscidæ* with a completely parasitic life.

The eggs of the Muscidæ usually hatch in a day but sometimes larvæ

* There is an excellent coloured plate (Plate LXVIII) of some Indian Tachinids, after Van der Wulp's water-colour drawings in H. Maxwell Lefroy's "Indian Insect Life" Calcutta 1909.

F. M. Van der Wulp's "Catalogue of described Diptera from South Asia." The Hague, 1896, mentions under fifty Indian species and is otherwise far from perfect.

are deposited, the eggs having hatched within the body of the parent fly. In this respect the same conditions prevail as in some *Sarcophagidæ* and some *Tachinidæ*. The typical Muscidæ are house-flies, blue-bottles and blow-flies. In the sub-family *Calliphorinæ* there are several grades of parasitism. All the species are oviparous, so far as we know, and usually the eggs are deposited on dead bodies. The stages towards parasitic habits are as follows :—

(*a*) Some flies will occasionally lay their eggs in sores on the skin of living animals where the larvæ can feed on the juices that surround them. The larvæ of *Calliphora vomitoria* L. a common European and American member of the blue-bottle genus, occasionally cause cutaneous myiasis in man and animals. The allied *C. erythrocephala* Macq. is found in North India and may sometimes have the same habit. *Lucillia serenissima*, Fabr., a greenish medium sized fly common about the meat stalls at bazaars in South India, as a rule deposits its eggs on dead meat. Occasionally it will oviposit on sore places in the skin of sickly cattle. This often happens during outbreaks of foot-and-mouth disease in Madras.

(*b*) The next stage begins where this has become the regular habit as is the case with many species belonging to several genera. *Pycnosoma* is a genus to which belong the Oriental representatives of the genus *Chrysomyia* which in tropical America cause serious myiasis in men and beasts. They are thick-set insects with characteristic red cheeks. *P. flaviceps*, Walk., a well known species in South India, deposits its eggs in the nostrils particularly of human beings and camels. The female flies are attracted by foul breath. The larvæ penetrate within the nasal and frontal sinuses producing ulceration, fever and sometimes death.

(*c*) The latest stage of parasitism is the blood-sucking maggot. The two genera *Auchmeromyia* and *Chœromyia* which have developed this habit are both African. The Congo floor-maggot has already been referred to. The larvæ of *Chœromyia* inhabit the lairs of wart-hogs and aard-varks whose blood they suck.

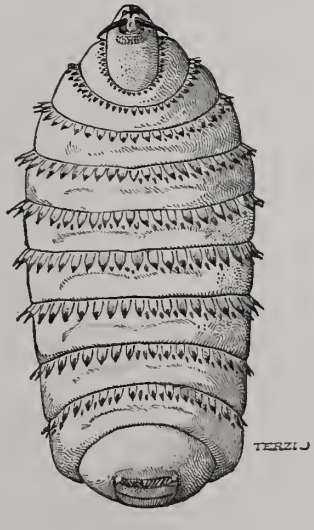
Sarcophagidæ. The flesh-flies, as they are commonly called, are a family of few genera but there are many species and they are difficult to distinguish. The larvæ sometimes live as parasites in wounds and sores causing dermal myiasis. They have also been discovered in the nasal cavities of man and other mammals. Whether this is one of the regular reproductive habits of definite species is not certainly known. The genus *Sarcophaga* is sometimes and perhaps habitually larviparous. These larvæ have been found living in the stomachs of frogs and under the skin of turtles. The larvæ of several species have been also found in snails, beetles, grass-hoppers and in the larvæ of moths.

These flies are common all over India. They may be recognised

5

6

6A



6B

INDIAN PARASITIC FLIES.

5.—*Conops erythrocephala*, Fabr. ♀. x 4.

6.—Larva of *Gyrostigma sumatrensis*, Brauer. (After Bau.) x $2\frac{1}{4}$.

6A.—Larva of *Gastrophilus equi.*, Clark. x 3.

6B.—Larva of *Cobboldia elephantis*, Cobbold. (After Bau.) x 3.

by their red eyes and grey thorax striped longitudinally with black. They are thick-set flies of moderate size and frequent the neighbourhood of decaying animal and vegetable matter. The known Indian species nearly all belong to the genus *Sarcophaga* and the commonest Indian species is probably *S. lineatocollis* Macq. In Gujarat it is not uncommon to see large sores on the human scalp full of the larvæ of a species of *Sarcophaga*; whether such larvæ truly deserve the name of parasites depends on how far this method of nutrition is an established and regular habit.

Œstridæ. The flies of this family are sometimes included among Calyptrate Muscoids but are best regarded as a distinct group which has arisen from several Muscoid types and now is much specialised for a parasitic life. They form a small and well defined group with about seventy or eighty described species scattered over the world. The larvæ are always parasitic on mammals and on mammals only. The hosts of the Indian species are horses, sheep, cattle, elephants, rhinoceroses and camels. The note-worthy feature in the life history of an Œstrid fly is that feeding is confined to the larval stage. This is the parasitic period when the growing insect lives surrounded by nourishment.

Parasitism of the larval insects takes three principal forms. We have parasities (1) in the food canal, (2) in tumours formed by the larvæ under the skin, and (3) in the normal cavities of the nose and throat. It is a general rule, with but few exceptions, that each species of Œstrid fly is confined to a single species of mammal; and allied species of fly are parasitic in the same fashion upon allied mammals. The adults are free-living, large, hairy flies, which take no food and exist only for procreation of their species. The adult fly has a minute mouth and often such atrophied vestiges of mouth parts that it is incapable of taking any food. Nevertheless some of these flies live for three or four weeks and display great activity.

Brauer classified the *Œstridæ* according to the combined characters of the larvæ and the perfect insects*. He divided the typical Œstrids into three groups, which coincide with a classification based on the parasitic habits of the larvae. His three divisions are the following:—

1. *Gastricolæ*. Larvae found in the stomach and gut of Equidae (Horses, asses, etc). *Rhinocerotidæ* (rhinoceroses) and *Proboscidea* (elephants). To this group belong *Gastrophilus*, *Gyrostigma* and *Cobboldia* which are all three Indian genera.

* Professor Friedrich Brauer of Vienna brought out his monograph in 1863. *Monographie der Œstriden*, by Friedrich Brauer. Wien, 1863. It was an epoch-making work and contains a complete bibliography of all the literature on the Œstridæ up to that year. It is still a standard authority in spite of much recent work on the group. See also "*Nachträge zur Monographie der Œstriden*", *Wiener Entom. Zeitung*, (1887) vol. VI., p.4. by F. Brauer.

2. *Cavicolæ*. Larvæ found in the frontal sinus, nasal cavity and throat of *Covicarnia* (cattle, sheep and other hollow-horned ruminants). *Tylopoda* or camels, *Cervidæ* (the deer family), *Proboscidea* (elephants). The Indian genera are *Œstrus* and *Cephelomyia*.

3. *Cuticolæ*. Larvæ found under the skin of *Cavicornia*, deer, the horse family and rodents. *Hypoderma*, so far as I can discover, is the only recorded Indian genus. This is the group to which the warble-flies belong.

Brauer enumerated sixteen genera in the whole Œstrid family and about half a dozen more have been established since his day. The adult flies belonging to this family are not difficult to recognise. They are fairly large and thick-set flies with big heads, of which the lower part is inflated, giving a sturdy appearance. The short, three-jointed antennæ are sunk in the front of the head and hardly visible. The compound eyes are not prominent, and there are also ocelli, or simple eyes. The abdomen is short, conical and often hairy, somewhat like that of a bee. The veins in the wings are like those of house-flies and others of the Muscid stock, from which the Œstrids are doubtless descended. The second pair of wings (as in all Diptera) are represented by small balancers called halteres. In many Œstrid flies the halteres are protected by scales, usually large, which are known as squamæ or tegulæ.

Much controversy has raged as to the manner in which the larval parasites reach their abiding place in the host's body. It is now generally believed that the eggs, or young larvæ, are, with some possible exceptions, taken into the mouths or nostrils of the animals which they infest, and so proceed, respectively, into the stomach, nose, throat and frontal sinus, or bore a way through the tissues of the body to the skin.

1. *Gastricolæ*.—The genus *Gastrophilus* has many species and a world-wide distribution. All are parasites of horses, wild asses and zebras. These flies are therefore restricted as regards geographical distribution by that of the *Equidæ*. Several species are common wherever men keep horses, and their larvæ are the horse-bots well known to grooms and veterinary surgeons. *Gastrophilus equi* Fab. one of the typical species is widely distributed in India. The female buzzes about horses during the hot hours of the day. Hovering a moment, she deposits a yellowish conical egg which adheres, like the nit of a louse, by its narrow end to the hair. This egg remains securely attached, owing to a viscid matter which is deposited at the same time. The fore legs, which are most accessible to the horse's tongue, are as a rule the parts selected. The flies are somewhat hairy, with fawn-coloured faces and blackish thorax. The abdomen is mottled yellow, with darker brown irregular blotches. The abdomen of the female ends in a long ovipositor, which is doubled beneath

the body when at rest. Though hundreds of eggs may sometimes be seen glued to the hairs of a single horse, the future host does not seem to be troubled by the performance. Hatching follows after a few days. Perhaps it is the itching caused by the larvæ which makes the horse lick the places. On reaching the alimentary canal, the parasites travel down and ultimately attach themselves by their mouth-hooks to the stomach wall. The place of attachment is marked by a depression, and the head of the larva becomes more and more deeply plunged into the mucous membrane. During this parasitic stage, which lasts ten months to a year and includes two moults and three stages of larval growth, the larvæ feed on the inflammatory products which exude from the minute wound. After the bots are detached from a horse's stomach the pitting remains.

The body of the Œstrid larva consists of twelve segments, of which the first two cannot be differentiated from the cephalic ring. No head can be recognised. The antennæ are rudimentary membranous papillæ. The problem of respiration during the parasitic time in the host's stomach presents difficulties which are, however, successfully solved. On reaching maturity the larvæ let go their hold and pass out of the horse's body with the droppings . The larvæ are then whitish oval maggots, about 20 millimetres long, with rows of brownish spines. They are at first lively, but soon burrow into the horse-dung or the earth, and there turn into rigid, dark-brown shiny pupæ. This stage lasts a month or more. The fly emerges by forcing open the lid of the puparium, and the life-cycle begins once more.

Indian elephants are the hosts of Œstrid larvæ which attach themselves to the stomach walls and go through stages of development similar to those of the horse-bots. The flies belong to the genus *Cobboldia*. The parasites of Asiatic elephants are probably of a different species from those which attach themselves to African elephants. The Indian insect, *Cobboldia elephantis* Cobb., is known, and is a large fly with conspicuous reddish head, black wings and body, marked with startling white spots at the base of each wing. Eggs of flies have often been observed in the erosions at the roots of elephants' tusks. It may be that this is the usual spot chosen by the Œstrids to deposit their eggs. Since elephants do not lick their fore-legs or flanks like horses, a spot near the root of the tusk gives the newly hatched larvæ the best likelihood of making their way into the gut of the proboscidean. The mature larvæ, which have long been known in the stomachs of elephants, are much larger than horse-bots, though of the same type. Their mouths are furnished with only a single pair of strongly curved hooks which act as formidable organs of attachment to the stomach membrane.

The history of our knowledge of this parasite of the elephant is interesting. Cobbold collected the first larvæ from Indian elephants

which succumbed to an epidemic in Sanger's Circus. Dr. Livingstone, the explorer, subsequently sent home specimens from African elephants. Brauer's own account of how he reared the first known flies from larvæ obtained from the dung of some newly arrived Indian elephants in the Imperial Austrian Menagerie at Schönbrunn is a delightful tale that may be recommended to all dipterologists.*

In this group of Œstrids there remains to be mentioned the genus *Gyrostigma*, which is parasitic on rhinoceroses. The larvæ have been obtained from the stomachs of two species of Asiatic rhinoceros namely *R. sumatrensis* and *R. lasiotis*. They resemble in most characters the *Gastrophili*, or horse-bots, but are larger. Since both species of African rhinoceros are the hosts of allied Œstrid larvæ it would be surprising if the rhinoceroses of the Indian peninsula were exempt from these parasites. Sportsmen who have an opportunity should examine the stomach walls of newly killed rhinoceroses and should detach the larvæ, if they are found, without injuring them. They should be preserved in alcohol.

Elephants, as is well known, are ancient types of mammal which have long existed on the earth. The evolution of mammalian host and insect parasite must have proceeded simultaneously during the long ages of the earth's history. *Cobboldia*, the elephant parasite. is therefore of special interest. The imago is a synthetic type which unites the characters of almost all forms of genuine Œstrid flies. The origin of the elephant is lost in the obscurity of geological ages, whilst the horse and the rhinoceros are both more recently evolved types of mammal and allied to one another. It is also significant, when we appreciate the relationship of the hosts, that the parasites of the horse and the rhinoceros belonging to the Œstrid genera *Gastrophilus* and *Gyrostigma* respectively are closely related. The deduction which may be drawn from these facts is that the parasitism of Œstrid flies on mammals is of ancient origin. Host and parasite have evolved into their present form side by side : and where the mammalian hosts are allied, the parasitic larvæ, which live in their stomachs, will turn into more or less closely related flies.

Cavicolæ. This group comprises some fifteen or twenty species of Œstrid flies, whose common characteristic is that the larvæ live in the cavities within the skulls of a variety of mammals. Sheep, antelopes, goats, buffaloes, camels,deer, horses and the African elephant and hippopotamus are the hosts of these remarkable parasites. In many cases only the larva has been obtained and the adult fly is still unknown. Six or seven species of the genus *Œstrus* are known, but the only recorded Indian species appears to be *Œstrus ovis* L. which has been known to man from ancient times. It is said to be

* "Beiträge zur Kenntniss aussereuropäischer œstriden", by Dr. F. Brauer (1896) Denks. Akad. Wiss. Wien, vol. 64 p. 259.

not uncommon in Bengal. The nasal fly, bot or head-maggot of sheep must have attracted the notice of shepherds in all ages. The fly is now found in all four continents and in Australia, the parasite having, thanks to man, travelled round the world with its host, but whether introduced or indigenous to India is uncertain.

The adult is rather a small fly, but larger than a house-fly, and of a yellowish-grey mottled and hairy appearance. Like other Œstrids, it avoids the shade and loves the hot bright sunshine. During inclement weather it hides and emerges in the warmth, to fly with much liveliness at a great height and to bask on stones heated by the sun. According to some observers the approach of the flies alarms the sheep, who huddle together with heads down and bury their noses in the dust. After being touched about the nostrils by the female fly, they snort and rub their noses on the ground According to other observers, the fly has been seen to settle on the nostrils of the sheep, and to deposit as many as fifteen eggs in succession, without causing any immediate annoyance to the future host.

There has been divergence of opinion as to whether eggs or larvæ are deposited, but there is little doubt that in Europe both habits obtain. It has been suggested that this depends on the weather.* The pregnant female, if the weather is fine, deposits eggs round the sheep's nostril. But if low temperature makes her inactive, the ova develop within the body of the parent during the period of delay. Larvæ are then laid in the sheep's nostrils. The larvæ enter the nasal cavities of the sheep, creep into the frontal and maxillary sinuses, even into those of the horn-cores, and there develop. They pass through the usual three stages of an Œstrid larva. In the first stage they are white and transparent, with a length of 2 millimetres. When they have attained maturity they develop dark transverse streaks, and sometimes attain a length of 30 millimetres. The parasites remain about ten months in these cavities of the head, feeding on the mucus. It is not unusual to find three or four together, and at the suitable season they may be found together in all stages of development. Yet they rarely occasion any morbid disturbance in the host unless they are far advanced in development and exceedingly numerous. During the months of larval growth they attach themselves by their mouth-hooks to the membranous lining of the cavity. On attaining maturity, the larva lets go and creeps about until it passes into the nose, from which it is expelled on to the ground by the violent snorting of the host. There pupation takes place within twenty-four hours. The pupal envelope, at first red, becomes brown and ultimately black. In about a month the perfect fly emerges and another life-cycle begins. So far as is known, the life-history of the other members of this group is somewhat similar. Other species of

* "Note on the Deposition of the Eggs and Larvae of *Œstrus ovis*, Linn.", by Walter E. Collinge, *Jour. Econ. Biology*, (1906) vol. I, p. 72.

Œstrus have been obtained from various wild sheep and from some African antelopes.

An interesting species *Cephalomyia maculata* Wied. is a parasite of camels, and the larval stage is passed in the nose or throat of the host. Both the Bactrian and the one-humped camel suffer from this fly. It is a small species, with thorax mottled yellow and black and abdomen blackish-grey. The head is broad and has a strangely swollen appearance. The wings are small, cut away at the hind margin, and mottled yellow along the anterior border. The halteres are masked by large scales or tegulæ. The larva reaches, when mature, a length of 30 millimetres. It is then sneezed or spat out by the camel. It at once pupates, and, if kept under observation in a box of sand, the fly will be seen to emerge in about fourteen days. This species ranges across North Africa eastwards into India, and is also found in South Europe. It is the only representative of the genus so far discovered. Camels appear to suffer from the presence of the parasite, and during various campaigns in Afghanistan and India the camels in the British expeditionary forces suffered severely. The continuous irritation produced in the nasal cavities and pharynx is followed by snorting and shaking of the head, with much exhaustion and a bloody and offensive discharge from the beast's nostrils. If it should be proved that the same species is also a parasite of such a totally different host as the buffalo (*Bos bubalus*) of Southern Europe and Asia, as has been asserted by some authorities, it would indeed be remarkable. The evidence is not conclusive and it is a general characteristic that Œstrid flies restrict themselves to one host, or, at least, to closely allied species. To find the same form in a camel and an ox would upset many preconceived notions.

3. *Cuticolæ*. Fifteen to twenty species of *Hypoderma* are known, whose larvæ are parasitic on horses, oxen, buffaloes, American bisons, goats, deer, antelopes and musk-deer. The insects are known as warble-flies. Domestic cattle in India are the victims of a Palearctic species *H. bovis*, De Geer, which is nearly allied to *H. lineata*. There is uncertainty as to their exact geographical distribution and whether their life-histories differ to any great extent.* The late Miss Ormerod spent over ten years in collecting the evidence of farmers and hide-merchants as to the injuries to cattle and hides. She estimated that 48 per cent of the hides exported from India were damaged by reason of the holes which the larvæ bore in them. There is little exact information as to the distribution of *H bovis* in India. It seems to be found in Western India from the Punjab southwards probably as far as Gujerat. In Bengal it is confined to the hills. When the female fly approaches the herd of cattle to lay her eggs, the beasts often stampede into the nearest water, where it is supposed the flies

* A good summary of what was known in 1906 was put together by A. D. Imma On the Life-Histories of the Ox Warble Flies," *Jour. Econ. Biology.*, vol. i., p. 74

do not follow them. This terror is attributed to a shrill buzzing made by the fly. The flies certainly neither bite nor sting the cattel. The female has no instrument, as many parasitic flies have, capable of inserting an egg under the host's skin. Her ovipositor is a flexible tube which opens and shuts in the manner of a telescope.

The flies move with such extreme rapidity that they are difficult to follow with the eye. They are rare in collections. The evidence seems to show that it is through the mouth of the host that the parasites reach the warbles, or subcutaneous tumours, in which they go through the last stages of their larval development. The female is so quick in performing the act of laying that she does not seem to remain on the host for more than a few seconds. The eggs are longish, flattened, white, with an appendage at the base which is perfectly adapted for clasping a hair. A number are often placed on a single hair. The appendage consists of two lobes, which form a bulbous enlargement at the base of the egg, and are attached to it by a thin neck. The lobes close over the hair and give a secure hold as soon as the egg is deposited. The eggs are laid on the backs and flanks of the cattle, perhaps on any spot which the beast's tongue can reach.

Once the eggs are laid, three possible courses have been put forward by different entomologists for the life-history of the parasite between the egg and the warble stage. *First*, that on hatching the larva eats its way through the hide and wanders a short distance in the subcutaneous tissues; eventually it returns to the surface and gives rise to the well-known tumours, in which it lives until the time for pupation arrives. Or, *secondly*, having bored a way through the skin, the larva wanders extensively in the tissues of its host, sometimes reaching the spinal canal and the walls of the œsophagus. Eventually it returns to the surface and completes its development beneath the skin. Or, *thirdly*, that the larvæ never bore through the skin of the host, but are taken into the throat when the beast licks the eggs off its body. Having hatched, the larva slowly bores through the walls of the œsophagus and wanders about the tissues, sometimes reaching the spinal canal through the spaces between the vertebræ. Eventually it reaches the skin as before.

There are grounds for believing that the last is the normal life-history. During the early part of the larval life, growth would seem to be very slow, but the small parasite may wander far and wide through the host's tissues. This is the winter period. Brauer called this stage the *Stillstandstadium*, and pointed out that a similar period of slow growth occurred in other larvæ of the Œstrid family*.

When the eggs are laid, the young larvæ within are already well developed. Sometimes they are licked up with the hair attached and the larva inside, at other times they may have already hatched.

* "Ueber das sogenannte Stillstandstadium in der Entwickelung der Oestriden Larven," by F. Brauer (1892), *Verhandl. Zool-Bot. Gesellschaft Wien*, vol. 42 p. 79.

In either event the moisture and warmth of the beast's saliva seem to conduce to their development. It is specially to be noticed that the season of egg-laying coincides with the time when the cattle are shedding their coats and have the habit of licking themselves.

The newly hatched larvæ are worm-like, whitish and transparent; they have minute spines over most of their body, which cause them to adhere to the walls of the œsophagus. In that situation they soon moult and assume the smooth stage. In the smooth condition they bore through the œsophagal walls and wander slowly through the host's tissues. This period of migration lasts some nine months, during which period growth is extremely slow. Towards the end of winter, at least in Europe, they make for a point in the region of the animal's back and there penetrate the skin. A second moult then ensues, and the spiny character is once more assumed. Development is rapid and causes much inflammation. As it reaches maturity the larva grows still more spiny. It lives in the fully developed warble, feeding on the products of the inflammation which it causes and breathing through the hole in the skin. This period of life in the tumour lasts into the ensuing summer. The larva is then some 25 millimetres long, bluntly oval in form, with a warty appearance. Its skin has become thick, and a powerful coat of subcutaneous muscles has been developed. The prickles are larger and more numerous than in the previous stages. They are probably erected by the muscles and used to create irritation and a copious secretion of the pus on which the parasite feeds. During the period of rapid growth it is desirable that the parasite should have access to the external atmosphere and should enjoy a sufficient supply of oxygen. The larva therefore enlarges the hole through the hide and lies with the tail end, containing the spiracles, in the passage, and the head end, hanging downwards, in the cavity of the warble.

When the larva has become full-fed and reaches maturity, it works a way out through the aperture of the warble. In this the prickles on its skin assist, by preventing it from slipping backwards. This exit usually takes place at night, or at least between six in the evening and eight in the morning, a habit that was long ago known to Reaumur. By fixing little bags over the apertures of the warbles it has been ascertained that the larvæ never emerge during the middle of the day. The larva pupates on the ground, taking shelter beneath a stone or clod of earth. The pupa, which is formed in the old larval skin, is dark brown and rather flattened on one side. In about twenty-five days the perfect insect emerges by forcing open the lid at the front end of the puparium.

This account of the Indian Œstrids concludes the group of Cyclorhaphous flies. The next group brings us to the Diptera Pupipara which are imaginal parasites.

(To be continued.)